

Thysanura and Collembola exhibit certain specializations of structure and function, but these are of minor importance—Apterygota being essentially the most generalized group of insects. They exemplify a life cycle without metamorphosis and are, so to speak, larviform, but with the power of reproduction.

2. THE LIFE CYCLE OF THE ORTHOPTEROID ORDERS.

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The Orthopteroid insects (*sens. lat.*) include all such forms as have mouth-parts of the mandibulate type and undergo a gradual or "incomplete" metamorphosis.

As in other orders of insects, the extent to which the immature stages ("nymphs") diverge from the adult in form and structure is more or less proportional to the differences in environment and habits. Accordingly they may be divided into two groups, (1) those which are terrestrial throughout life, and (2) those in which the early stages are aquatic.

Group 1 includes the Blattoidea, Mantoidea, Isoptera, Zoraptera, Grylloblattoidea, Phasmoidea, Orthoptera, Dermaptera, Embiidina, Corrodentia and Mallophaga. Group 2 includes the Plecoptera, Ephemera and Odonata.

In Group 1 the habitat and feeding habits are not materially altered during the life cycle, so that the same structural adaptations are present throughout life, and the metamorphosis is entirely gradual, except at the last moult, when the wings, if present, and the genitalia undergo more or less marked changes. There is, however, little or no histolysis of larval structures. The number of moults is comparatively small, so far as known, being usually four to six, but sometimes reduced to two or increased to seven or eight. A pronymphal stage is sometimes present. The nymphs resemble the adults except in size, details of proportion, chaetotaxy, sculpturing and sometimes colour-pattern, and in the thinner cuticle. The number of antennal and occasionally tarsal joints sometimes increases with growth, and the ocelli, when present, may not appear until the last moult. The wings, when present, appear at an early stage,

usually the third or sometimes the second moult. Primitively they appear as caudo-lateral extensions of the meso- and meta-nota, from which they become separated at a later stage by a suture and a more constricted base.

The leading features in the life cycles of the orders of Group 1, so far as known, may be summarized as follows:

Blattoidea. Mostly nocturnal, hiding by day, with a tendency to be gregarious: feeding chiefly upon animal and vegetable refuse; eggs (16-50) arranged in two series in a horny ootheca, formed in the uterus, and carried for a time in the genital orifice; dropped in protected places without attachment; period of growth variable, 4 or 5 months to several years, but usually one brood annually; number of moults variable, generally 5-7. Hibernation in egg or nymph state. The adult males of some species differ considerably in form from the nymphs and the adult females. Styli of female disappearing at last moult, usually persistent in the male.

Mantoidea. Diurnal, solitary, living on foliage or on the ground, predaceous on other insects; eggs arranged in several series in a membranous or vesicular ootheca formed at the exit of the genital passage and attached to other objects, the number deposited varying enormously in different species (20-1000); incubation period varying according to season, a few weeks (summer) to 10 months (winter); hatching as a pronymph; number of moults 7 or 8 (Mantis); usually one brood; hibernation in egg or nymphal stages. Styli as in *Blattoidea*.

Isoptera. Cryptozoic, living in communities, often of many thousands of individuals, which are polymorphic, there being in addition to the fertile adults and nymphs, sterile wingless castes of one or two types (soldiers and workers) and sometimes reserve fertile individuals (substitution royalties), which in other respects remain immature. Reproductive activity limited to few individuals, the kings and queens, (and the substitution royalties), the queens of enormous fecundity, and having the final or reproductive stage greatly prolonged (sometimes several years). Superfluous winged adults leave the colony, flying in swarms, but soon lose their wings. Food largely of wood, proctodæal excreta, saliva and organic refuse, varying in composition according to caste. There are generally no special modifications in the nymphs, except the lack of eyes and

the very thin cuticle, associated with the cryptozoic life. The number of antennal segments increases with development. Large prothoracic expansions are present in the nymphs of some species.

A few species of Isoptera are inquilines in the nests of other species of the same order.

Zoraptera. Inquilines in the nests of certain Isoptera; life cycle unknown.

Grylloblattoidea. The single species is alpine, living under stones and on snow; carnivorous (has been fed on ant pupæ); metamorphosis practically confined to the genitalia; styli present except in adult female. Hibernating as nymph or adult.

Phasmoidea. Phytophagous, generally on trees and bushes; voracious and reaching in some species an enormous size. Eggs few (12-100), each in a separate seed-like capsule, dropped at random. Incubation period sometimes extending over two years. Period of growth variable, 6 weeks to 16 months; number of moults few, variable, two or three in known cases. Nymphs usually not differing much from adults.

Orthoptera. Diurnal or nocturnal; arboreal to subterranean; phytophagous or partly carnivorous. Eggs moderately numerous, buried in plant tissues or in the ground by an ovipositor (except in subterranean forms); in the Acrididæ imbedded in a vesicular ootheca. Incubation period generally over winter in temperate climates, comparatively few species hibernating as nymphs or adults. Generally one brood, moults 4 to 6. An inversion of the wings takes place at about the fourth moult, the hind wings overlapping the front, until the final ecdysis, when the normal position is restored and the hind wings folded. Otherwise the nymphs are usually lacking in special modifications, though the color pattern is sometimes distinctive.

Dermaptera. Carnivorous and phytophagous; eggs dropped at random but sometimes picked up afterwards by female and carried to places of safety; in *Forficula auricularia* deposited in early spring; period of growth in this species about 5 weeks; moults 3 or 4. One or two broods, hibernating at various stages. Special form changes: Increase in the number of antennal segments; cerci of a few primitive genera segmented in the nymphal stages.

The aberrant African genus *Ilemimerus*, parasitic on rodents, is viviparous.

Embiidina. Living under damp stones and wood on the ground, nests of ants or termites, in small colonies but not forming societies; the nymphs constructing passages lined with a silk-like secretion from glands in the maxillæ; partly carnivorous, partly phytophagous; nymphs very similar to adults. Tropical or sub-tropical.

Corrodentia. On bark, under logs, old books, etc., feeding on animal and vegetable refuse, mouldy substances, etc. Eggs laid in patches or clusters under bark, or in other protected places, covered with a web; incubation period generally during winter in temperate climates. Period of growth probably short, there being sometimes two or perhaps three broods. Number of moults said to be four in *Psocus*. Nymphs resembling adults but without ocelli, which are present in the adults of winged species.

Mallophaga. Epizoid on birds and mammals, feeding on feathers, epidermal debris, etc.; eggs glued singly to hairs or feathers in the area inhabited by the insect, sometimes localized in groups common to many individuals. Incubation period not known definitely for any species, probably long; number of moults also unknown, apparently few. Length of life probably several months in most cases.

In Group 2 the nymphs, or *naiads*, differ from the adults more widely than in group 1 in correlation with the greater difference in environment. The period of growth is usually longer, being frequently three years, and the number of moults greater. Length of life cycle is to some extent proportional to size attained.

Plecoptera. The stone-flies show least divergence between larval and adult structure. The adults are feeble insects of secretive habits, serving only for the function of reproduction. Eggs small, carried by the female for a time in a mass at the genital orifice, and finally dropped freely into the water. Naiads inhabit well aerated water, clinging to undersides of stones, to which habitat they are adapted by the possession of filamentous tracheal gills, chiefly thoracic, and by their flattened form and legs, the latter fringed with swimming hairs. Food of naiads smaller aquatic animals. Length of life probably one to three years; number of moults not known for any species, probably very variable. Adults appear usually early, sometimes emerging on ice and snow, the order having on the whole a remarkable power of withstanding cold.

Ephemerida. Naiads phytophagous, diverging from the adults more widely than in the Plecoptera and showing a wider range of adaptation in form and structure. Life cycle varying from a few weeks to three years, aquatic except in the last two stages (subimago and imago), both of which have functional wings but live only a few hours to a few days and take no food. Number of moults large, apparently sometimes 30 or more. The most marked changes acquired on reaching the subimago stage are the enlargement of the compound eyes, the development of ocelli, reduction of antennæ and mouth-parts, development of wings and genitalia, loss of the tracheal gills, elongation of the cerci, with loss of their setæ, besides more or less marked changes in general form. Adult phase generally appearing in early summer, usually crepuscular or nocturnal and serving only for the mating function. Eggs deposited in large numbers, without capsule, sometimes attached to other objects.

Odonata. The habitats and corresponding modifications of the naiads of this group are similar to those of the preceding, but their habits are wholly predaceous. Developmental period varying from a few months to three years or more, the number of moults variable, even in the same species, 11 to 15 in known cases. A pronymphal stage is present.

The principal adaptations of the naiad are: Modification of the labium as a prehensile arm; (2) special respiratory organs, viz., three leaf-like terminal tracheal gills in the suborder Zygoptera, which also serve as fins, or numerous gills in the rectal chamber in the suborder Anisoptera. Wing pads of naiads reversed in position as in Orthoptera. Adults comparatively long-lived, active, predaceous, diurnal, showing the following changes of structure at the final moult in relation to the change of habits: Enormous enlargement of compound eyes and development of ocelli; shortening and change of form of labium, the larval structure being absorbed by histolysis; modification of thoracic segments and legs in adaptation to habits of flight and perching; elongation of abdomen and development of genitalia. There is a short quiescent stage, equivalent to a pupa, in which no food is taken. Oviposition endophytic or exophytic, the eggs in the latter case being sometimes scattered, sometimes enclosed in a gelatinous envelope, or attached to objects in water; generally several hundred deposited.